[redacted]

BELLCOMM, INC.

COVER SHEET FOR TECHNICAL MEMORANDUM

Ref. No. 65-2012

TITLE- Interim Report for AES Flight Mission Assignment Plan - Part III: Extended CSM Spacecraft (U)

TM- 65-1011-2

FILING CASE NO(S)- 218

DATE- January 29, 1965

AUTHOR(S)- K. E. Martersteck

FILING SUBJECT(S)- (ASSIGNED BY AUTHOR(S)) Apollo Extension Systems

CLASSIFICATION CHANGED

UNCLASSIFIED

TO

By Authority of Ltr Bellcomm Date 12-4-70

Get DRF

ABSTRACT

A general-purpose extended CSM (XCSM) spacecraft has been investigated for use in the AES program. The proposed XCSM would provide the desired hardware flexibility to the program at the cost of a relatively small loss in payload on some missions for which the spacecraft would not be completely optimized. The XCSM would be capable of supporting a three-man crew on missions up to 45 days in earth orbit or on lunar missions such as a 28-day survey.

The XCSM, which has an estimated inert weight of about 27,000 pounds, would be derived from the Block II Apollo CSM by a set of AES modifications including an increased supply of expendables and cryogenics and the addition of redundancies and spares for improved reliability. More than 2000 pounds in added RCS capability for mapping purposes, which need not be carried on non-mapping missions, are included in the estimated XCSM weight.

The lifetime of the Apollo CSM may be extended to about 21 days in earth orbit primarily by means of a "plug-in" addition made in sector 1 of the service module. This would be possible if about 50 pounds of "scar-weight" (brackets, connectors, etc.) for this purpose were built into the Block II SM. Such a 21-day CSM would be most desirable for AES use during the period after the first lunar landing before XCSM spacecraft are available.

SUBJECT: Interim Report for AES Flight Mission Assignment Plan - Part III: Extended CSM Spacecraft (U) Case 218

DATE: January 29, 1965

FROM: K. E. Martersteck

TM - 65-1011-2

TECHNICAL MEMORANDUM

1.0 INTRODUCTION

The Apollo Extension Systems (AES) have been proposed to implement the major objectives of U. S. manned space flight operations, namely exploration and scientific investigation of near-earth space and of the moon. In order to accomplish these objectives, systems must be designed for application to earth orbital and lunar exploration. In addition they must be flexible enough to be able to be shifted to meet new opportunities which may develop as the program progresses. Such versatility requires that the major elements of the Apollo Extension Systems be able to operate in several modes. However, the major AES hardware elements are to be truly extensions of Apollo hardware and not new developments.

A number of studies into methods of increasing Apollo spacecraft capabilities have been undertaken. In the current design of the Block II Command/Service Module (CSM), the operational lifetime has an upper bound of about twelve days, set primarily by the capacity of the cryogenic system. Based on the studies of CSM lifetime extensions, launch vehicle capability and systems reliability, the preliminary AES flight mission assignment plan includes three general manned-mission types: earth orbital missions of 30-45 days duration, lunar orbital missions of 28 days plus translunar and transearth time, and lunar surface missions of 14 days plus transit time. In order to accomplish the proposed AES missions successfully with modified Block II CSM spacecraft, the following types of modifications must be made:

(a) Increase the spacecraft supply of expendables for the environmental control, electrical power, reaction control, and crew systems.

(b) Modify certain systems to perform specific AES missions functions (e.g., adapt the stabilization and control system for mapping attitude control).

(c) Add redundancies and spares to various spacecraft systems to meet the mission reliability goals.

[redacted]

[redacted]

[redacted]

The changes mentioned in the first category will probably be the most extensive and involve the major spacecraft weight change. Further details are given below.

2.0 MODIFICATION SCHEMES

How can these modifications most effectively be made while adhering to the AES ground rules? Two possible answers are: tailor each spacecraft for a specific mission or produce a general-purpose CSM which could perform any AES mission.

2.1 UNIQUE SPACECRAFT FOR EACH MISSION

By adopting this approach, spacecraft weight can be reduced to a minimum by optimizing the spacecraft for each mission, thereby allowing greater experimental payloads to be flown. Furthermore, the spacecraft systems could be altered to be more compatible with the particular experiments being flown in order to yield better experimental results. On the other hand, such an approach would undoubtedly require more extensive modification, depending on the degree to which the "tailoring" were carried out, and would lead to a proliferation of custom built spacecraft. Since spacecraft would not be interchangeable between missions, a serious loss of the flexibility for which the AES program is striving would result.

2.2 GENERAL-PURPOSE SPACECRAFT

With this approach, all modified AES spacecraft would be essentially the same regardless of their mission assignment. They would be sized for the longest mission with the capability to perform the most difficult mission. Any experiments carried in the CSM would, however, still be uniquely designed for a given mission. This approach would result in a heavier-than-necessary spacecraft for some missions; however, spacecraft development would be more efficient and the operational flexibility resulting from interchangeable spacecraft would be available.

Of these two possibilities, the more prudent choice appears to be to adhere as closely as possible to the concept of a general-purpose spacecraft. In most cases the advantage of flexibibility appears to be more important than the relatively small loss of payload. This is particularly true in the earlier phases of the AES program when it should dove-tail neatly with the mainstream Apollo program and when results from early AES flights may indicate the need for changes in schedule or program emphasis in order to take advantage of newly-acquired knowledge. Furthermore, the latter approach involves a less complex modification program, from both technical and managerial aspects, and further follows the "Block" philosophy already in use in the Apollo program. For these reasons it was decided to investigate the modifications necessary to provide an all-purpose extended CSM (XCSM) for use in all but the first stages of the AES program.

In the early stages of the AES program, because of the AES ground rules dictating non-interference with Apollo, at least a year or more delay will occur between the first "assured" lunar landing and the availability of a supply of modified spacecraft for AES. (Scheduling details are discussed in Part VII of this report.) During this interim period, only unmodified spacecraft with limited capability will be available for the AES program making it difficult to determine worthwhile missions. However, if a relatively small amount of "scar-weight" material, such as brackets and plumbing connectors, were added in sector 1 of the Block II service module, a plug-in modification could be made which would extend the lifetime capability of the Block II CSM for earth-orbital missions to about 21 days. This alternative has also been considered in more detail below.

3.0 MODIFIED SPACECRAFT WEIGHT

In order to determine the longest and most difficult missions for the AES, tradeoffs must be considered among weight, lifetime capability and reliability of spacecraft systems, experimental payload required to return worthwhile information, and launch vehicle performance for the desired mission profile. (Launch vehicle performance and payload weights are discussed in Part II of this report). According to the North American Aviation, Inc., Apollo-X Final Report (SID 64-1860, Contract No. NAS 9-3140), the CSM could be extended to 90 days duration in earth orbit. However, based on Saturn IB limits by which the spacecraft must be sized in order to retain the Saturn IB - Saturn V flexibility, this 90 day version of the CSM leaves no weight for any experimental payload or for a laboratory module. Also, such a spacecraft would not have lunar-survey-mission capability. A mission duration of about 45 days now appears to be more reasonable from both payload and systems reliability considerations. From the performance aspects, a long-duration (28-day) lunar mapping mission is the most difficult. It puts near-maximum demands on virtually every major spacecraft system. While of longer duration, earth orbital missions can tolerate lower reliability for the same crew safety and mission success probability because of the relative ease of return to earth and the shorter return time.

Thus the XCSM with a three-man crew can be sized for a 45-day earth orbital mission and can be capable of performing the functions of a 28-day lunar mapping. The resulting XCSM would have an estimated total inert weight of about 27,000 pounds divided roughly as follows: 12,000 pounds for the extended CM and 13,000 for the SM plus 2,000 for RCS. A detailed breakdown of the derivation of these weights is given in the Appendix. Since the added RCS weight is needed primarily for detailed mapping, it has been singled out as a possible exception to the all-purpose modification procedure. It might prove advantageous to provide this added RCS capability as a special "mapping-mission modification" and thereby free more weight for experimental payload on other missions.

Most of the additions to the service module are bulk items such as reactants, tanks, fuel cells, etc., which are inserted in a relatively straightforward arrangement. This accounts for the greater portion of the total weight addition to the XCSM. The additions to the command module are no less important, however. Besides essentials such as food and LiOH, these items include redundancies and spares which are needed to improve the command module systems reliability for the long duration missions.

The 27,000 pound figure is the inert spacecraft weight, that is, with no service propellant included. The SPS propellant capacity is about 40,000 pounds. The actual propellant loading may vary from full capacity for lunar missions to a minimum of about 1000 pounds required for reentry from low-altitude earth orbit. The spacecraft weight does not include the LEM adapter, which weighs about 3800 pounds. The XCSM total weight is given for a 45-day mission. If shorter-duration missions are flown, some expendables could be offloaded--approximately 75 pounds per day less than 45.

The assumption has been tacitly made that the added fuel cells and cryogenics would be installed in sector 1 of the SM and most of the experiments in a laboratory module. This arrangement is neither unique nor the only workable one. However, the purpose of this study is to give an indication of the amount of additional weight required to modify the Block II CSM for AES. This required weight is essentially unchanged regardless of where it is installed. Nevertheless it should be pointed out that the subject of optimum system arrangement in the extended spacecraft modules must be given further study.

4.0 SCAR-WEIGHT EXTENSIONS

During the interim period between the first "assured" lunar landing and the availability of modified spacecraft, it is desirable to have some means of extending the Block II CSM lifetime capability for AES missions. By taking the scar-weight approach (i.e., making minor modifications to Block II spacecraft) it would be possible to extend earth orbital mission times to about 21 days. This could be accomplished by inserting a "plug-in" addition to the cryogenic subsystem and EPS in sector 1 of the Block II SM. This scheme is feasible if, during the assembly of the SM, suitable brackets are installed and appropriate wiring, plumbing lines and connectors are brought over to sector 1. Then a structure containing a fuel cell and oxygen and hydrogen tanks could be readily inserted. The scar-weight would amount to an estimated 50 lbs. The plug-in addition and extra expendables for a 21-day mission would weigh about 1000 pounds (a detailed breakdown is given in the Appendix).

5.0 CONCLUSION

The Block II Apollo CSM can be modified to perform proposed AES missions of up to 45-days duration. While this is not the ultimate lifetime to which the CSM systems can be pushed, it does represent a reasonable limit based on spacecraft capability, reliability and payload. This extended CSM could be produced by means of a general-purpose-type modification consisting primarily of added consumables, redundancies and cryogenic subsystem capacity. The inert weight of the XCSM is estimated to be about 27,000lbs. (SPS propellant not included). The arrangement of the subsystem extensions in the various AES modules to provide maximum flexibility and minimum modification needs further study. It also seems possible to produce an interim XCSM capable of carrying out earth orbital missions of about 21 days duration by the addition of approximately 1000 lbs.

The major problem would be the actual accomplishment of the spacecraft modification. The question of how and where all these modifications would be made has not been considered. The problem of integration of any experiments into the CSM has not been probed either. Further study in these areas will be required to ensure a smooth operation.

There are many lesser problems which arise when extending the capability of various CSM systems, e.g., the storage of the additional 11 cubic feet of LiOH canisters needed for CO_2 removal. Such problems will have to be faced during a more detailed look at the XCSM. The basic XCSM concept appears sound nevertheless.

K. E. Martersteck

1011-KEM-mph

K. E. Martersteck

APPENDIX

A1.0 XCSM Modification Weight

This appendix details the weight changes required in the extended command and service modules for the AES missions. The weight additions tabulated below include sufficient expendables for a 45-day mission and spacecraft capability for a 28-day lunar survey mission. All weights have been estimated to the nearest ten pounds.

EXTENDED COMMAND MODULE WEIGHT (lbs.)

System	Weight Addition
SCS	60
G&N	80
Crew Systems	200
EPS	60
Communications	50
ECS	350
Total	800
Block II CM Control Weight	11,000
XCM Total	11,800

The additions to the stabilization and control system (SCS) and guidance and navigation system (G&N) are for modifications to electronics and logic for precise attitude control, e.g., addition of a horizon sensor, redundancy and spares for improved reliability (weights estimated from Apollo-X Report, Vols. 2 and 17).

The Block II CM carries 38 man-days food supply. To complete a 45-day mission a three man crew requires an additional 97 man-days supply. Thus 200 pounds more food (consumed at about 2 pounds per man per day) are included under crew systems.

Redundancy and spares account for the extra weight shown in the XCM for the electrical power system (EPS) and communications system (estimated from Apollo-X Report, Vols. 4 and 18). EPS equipment located in the CM includes both AC and DC power distribution systems. In addition to improving the reliability of the communications system, it may be desirable to upgrade the system capacity, particularly between CM and LEM for occasions when the two modules are separated.

For CO_2 removal in the CM environmental control system (ECS), there must be an additional 100 man-days supply of LiOH, which is used at the rate of 3 pounds per man per day. The storage of this 300 pounds of LiOH (about 11 cu. ft. in volume) may prove to be a problem. It has been assumed that some LiOH canisters can be stowed in a laboratory module. The problem could be avoided if the ECS were redesigned to incorporate a molecular sieve for CO_2 removal. Fifty pounds are allowed for minor modifications of the ECS to improve its long-duration capability, e.g., addition of a catalytic burner for removal of trace contaminants and a redundant compressor circuit.

EXTENDED SERVICE MODULE WEIGHT (lbs.)

System	Weight Addition
ECS	360
EPS	2,530
Total	2,890
Block II SM Control Weight	10,000
XSM Subtotal	12,890
XCSM Subtotal	24,690
RCS	2,200
XSM Total	15,090
XCSM Total	26,890

The ECS weight added in the SM is for oxygen, which is consumed at the metabolic rate of 2 pounds per man-day and at a leakage rate of about 5 pounds per day. The additional tankage required to store this oxygen is accounted for along with EPS tankage.

In the Apollo-X Report, Vols. 2 and 4, NAA recommends adding 2 fuel cells (about 250 pounds each) to extend the capability and reliability of the EPS. This is probably an optimistic recommendation based on fuel cell performance to date. However, recent indications from Pratt & Whitney, the fuel cell contractor, are that the situation is improving. There is room in the SM to add a third additional cell if it should be needed. For an estimated average power consumption of 1.8 kw, 1540 pounds of supercritical reactants (140 pounds of hydrogen and 1400 pounds of oxygen) and 490 pounds of tanks must be added (Vol. 9, Apollo-X Report).

The RCS requirements for mapping missions have been set apart as a possible exception to the general-purpose XCSM concept. The 2,200 pounds indicated (600 for tanks and 1600 for propellants) was estimated by NAA (Apollo-X report, Vol. 2). The mission profile for lunar mapping is under study and may require less RCS capacity, depending on what coverage and attitude control finally prove to be necessary.

A2.0 SCAR-WEIGHT ADDITIONS

The CSM lifetime capability could be augmented somewhat by a plug-in addition to sector 1 of the SM and an increase in expendables stowed in the CM. The following table lists the weight changes in the CSM for a 21-day mission using this approach. Again, the weights have been estimated to the nearest 10 pounds.

21-DAY XCSM WEIGHTS (lbs.)

System	Weight Addition
Crew Systems	50
ECS	180
EPS	800
Total	1,030

The additional crew systems weight is for 25 man-days food supply, stored in the CM. Oxygen and LiOH constitute the addition to the ECS. One extra fuel cell, reactants, tanks and brackets must be added to the EPS.